

CLAIMS

What is Claimed Is:

1 1. A nerve stimulator needle apparatus comprising:
2 a needle capable of carrying an electric current;
3 a variable control mechanism which is operable to variably control the amplitude of an
4 application of electric current to said needle;
5 a plurality of electrical connectors connected to said variable control mechanism and said
6 needle which allows said variable control mechanism to remotely connect to a nerve stimulation
7 device which is operable to provide a voltage to said variable control mechanism and to provide
8 a current pulse to said needle having an amplitude which is controlled by said variable control
9 mechanism; and
10 a housing which holds said variable control mechanism, said plurality of electrical
11 connectors and said needle.

1 2. The nerve stimulator needle apparatus of claim 1, wherein said
2 needle is a hypodermic needle, said apparatus further comprising:
3 an injection tube operably connected to said needle to provide a fluid to
4 said needle.

1 3. The nerve stimulator needle apparatus of claim 2, wherein said
2 housing includes a fluid path, and said injection tube is connected to one end of
3 said fluid path and said needle is connected to another other end of said fluid path.

1 4. The nerve stimulator needle apparatus of claim 1, wherein said
2 variable control mechanism includes a pressure sensitive switching mechanism
3 which changes the amplitude of said current applied to said needle in relation to
4 the amount of pressure applied to said pressure sensitive switching mechanism.

1 5. The nerve stimulator needle apparatus of claim 1, wherein said
2 variable control mechanism is operable to increase or decrease current to the
3 needle.

1 6. The nerve stimulator needle apparatus of claim 1, wherein said
2 variable control mechanism is operable to control a rate of change of the current.

1 7. The nerve stimulator needle apparatus of claim 1, wherein said
2 housing further includes conductive traces which connect said variable control
3 mechanism and said needle to said electrical connectors.

1 8. The nerve stimulator needle apparatus of claim 1, wherein an
2 electrically resistive layer covers said needle, the resistance of said resistive layer
3 changes with the length of said resistive layer, and an electrical trace from an
4 electrical pin connector provides a voltage to said electrically resistive layer from
5 said nerve stimulator device.

1 9. The nerve stimulator needle apparatus of claim 8, wherein said
2 needle unit further includes an insulating layer between said electrically resistive
3 layer and said needle.

1 10. The nerve stimulator needle apparatus of claim 1, wherein said
2 needle unit further includes depth measurement marks which indicate the
3 insertion depth of said needle.

1 11. The nerve stimulator needle apparatus of claim 1, wherein said
2 variable control mechanism comprises a variable optical switching device.

1 12. The nerve stimulator needle apparatus of claim 11, wherein said
2 variable optical switching device includes a partially colored plate and a fiber
3 optic cable which directs light from a light source to impinge on said partially

4 colored plate, and directs reflected light from said partially colored plate to a
5 sensor.

1 13. The nerve stimulator needle apparatus of claim 12, wherein said
2 partially colored plate alters color or intensity components of the light impinged
3 on it from said fiber optic cable in response to an application of pressure.

1 14. The nerve stimulator needle apparatus of claim 11, wherein said
2 variable optical switching device includes a graduated reflective plate and a fiber
3 optic cable which directs light from a light source to impinge on said graduated
4 reflective plate, and directs reflected light from said graduated reflective plate to a
5 sensor.

1 15. The nerve stimulator needle apparatus of claim 14, wherein said
2 graduated reflective plate alters color or intensity components of the light
3 impinged on it from said fiber optic cable in response to an application of
4 pressure.

1 16. The nerve stimulator needle apparatus of claim 1, wherein said
2 needle is an insulated needle.

1 17. A nerve stimulator apparatus comprising:
2 a nerve stimulator device comprising:
3 a voltage source;
4 a controller; and
5 a current source operable to produce an electrical current in response to
6 said controller; and
7 a needle unit remotely located from said nerve stimulator device and
8 connected to said nerve stimulator device only by at least one electrical
9 conductor, said needle unit comprising:

10 a variable control mechanism which is operable to receive a voltage from
11 said voltage source and to provide instructions to said controller to variably
12 control the amplitude of said electrical current provided by said current source;
13 a needle capable of carrying said electric current from said current source
14 having the amplitude controlled by said variable control mechanism; and
15 a housing which holds said variable control mechanism and said needle.

1 18. The nerve stimulator apparatus of claim 17, wherein said needle is
2 a hypodermic needle, said apparatus further comprising:
3 an injection tube operably connected to said needle to provide a fluid to
4 said needle.

1 19. The nerve stimulator apparatus of claim 18, wherein said housing
2 includes a fluid path, and said injection tube is connected to one end of said fluid
3 path and said needle is connected to another other end of said fluid path.

1 20. The nerve stimulator apparatus of claim 17, wherein said variable
2 control mechanism includes a pressure sensitive switching mechanism which
3 changes the amplitude of said current applied to said needle in relation to the
4 amount of pressure applied to said pressure sensitive switching mechanism.

1 21. The nerve stimulator apparatus of claim 17, wherein said current
2 source is operable to increase or decrease current in response to the operation of
3 said variable control mechanism, and said variable control mechanism is operable
4 to increase or decrease current to the needle.

1 22. The nerve stimulator apparatus of claim 17, wherein the current
2 source changes the amplitude of said current in response to the operation of said
3 variable control mechanism and said variable control mechanism is operable to
4 control the rate of change of the current.

1 23. The nerve stimulator apparatus of claim 17, further comprising
2 electrical connectors mounted to said housing, wherein the electric current is
3 provided through said electrical connectors.

1 24. The nerve stimulator apparatus of claim 23, wherein said housing
2 further includes conductive traces which connect said variable control mechanism
3 and said needle to said electrical connectors.

1 25. The nerve stimulator apparatus of claim 17, wherein said needle
2 unit includes an electrically resistive layer covering said needle, wherein the
3 resistance of said resistive layer changes with the length of said resistive layer,
4 and an electrical trace from an electrical connector provides a voltage from said
5 voltage source to said electrically resistive layer.

1 26. The nerve stimulator apparatus of claim 25, wherein said needle
2 unit further includes an insulating layer between said electrically resistive layer
3 and said needle.

1 27. The nerve stimulator apparatus of claim 17, wherein said needle
2 unit further includes depth measurement marks that indicate the insertion depth of
3 said needle.

1 28. The nerve stimulator apparatus of claim 25, wherein said controller
2 includes a microprocessor, and said microprocessor determines the insertion depth
3 of the needle according to the equation:

$$4 \qquad L_b = (R_t - R_a) / r_L$$

5 where R_a is the resistance of the portion of the needle protruding above a
6 skin surface of a subject;

7 R_t is the resistance of the total length of the needle;

8 r_L is the resistance per unit length of the needle; and

9 L_b is the insertion depth of the needle.

1 29. The nerve stimulator apparatus of claim 25, wherein the value R_a is
2 calculated from the ratio of the applied voltage to the resistive layer on the needle
3 divided by the current detected by a return electrode attached to the surface of the
4 skin of a subject.

1 30. The nerve stimulator apparatus of claim 17, wherein said variable
2 control mechanism comprises a variable optical switching device.

1 31. The nerve stimulator apparatus of claim 30, wherein said variable
2 optical switching device receives light from a light source and includes a partially
3 colored plate and a fiber optic cable which directs the light from said light source
4 to impinge on said partially colored plate, and directs reflected light from said
5 partially colored plate to a sensor.

1 32. The nerve stimulator apparatus of claim 31, wherein said partially
2 colored plate alters color or intensity components of the light impinged on it from
3 said fiber optic cable in response to an application of pressure, and said sensor
4 converts said altered color or intensity components to a corresponding current
5 signal.

1 33. The nerve stimulator apparatus of claim 30, wherein said variable
2 optical switching device includes a graduated reflective plate and a fiber optic
3 cable which directs light from a light source to impinge on said graduated
4 reflective plate, and directs reflected light from said graduated reflective plate to a
5 sensor.

1 34. The nerve stimulator needle apparatus of claim 33, wherein said
2 graduated reflective plate alters color or intensity components of the light
3 impinged on it from said fiber optic cable in response to an application of
4 pressure.

1 35. The nerve stimulator apparatus of claim 17, wherein said needle is
2 an insulated needle.

1 36. A method of locating nerves comprising the steps of:

2 (A) inserting a needle mounted on a housing through a surface of skin of a
3 subject;

4 (B) activating a variable control mechanism mounted on said housing to
5 provide a variably controlled current to said needle;

6 (C) monitoring a detected current signal from a return electrode attached
7 to said surface of skin of a subject using a nerve stimulator device,

8 wherein steps A and B are substantially performed simultaneously by the
9 same hand of an operator.

1 37. The method of locating nerves according to claim 36, further
2 comprising the step of determining the needle insertion depth by providing a
3 voltage to a resistive layer, completing a circuit through a return electrode on the
4 skin surface.

1 38. The method of locating nerves according to claim 37, wherein the
2 step of determining the needle insertion depth is performed according to the
3 equation:

4
$$L_b = (R_t - R_a) / r_L$$

5 where R_a is the resistance of the portion of the needle protruding above a
6 skin surface of a subject;

7 R_t is the resistance of the total length of the needle;

8 r_L is the resistance per unit length of the needle; and

9 L_b is the insertion depth of the needle.

1 39. The method of locating nerves according to claim 38, wherein the
2 value R_a is calculated from the ratio of the applied voltage to the resistive layer on

3 the needle divided by the current detected by the return electrode attached to the
4 surface of the skin of a subject.

1 40. The method of locating nerves according to claim 36, wherein the
2 determination of the needle depth comprises the steps of:
3 continuously applying a constant current to a resistive layer on the surface
4 of said needle;
5 periodically applying a current pulse to said needle while applying said
6 constant current;
7 waiting for a period of time to elapse after applying said current pulse to
8 said needle and determining the resistance of the resistive layer of said needle
9 exposed from the surface of skin of the subject; and
10 calculating the depth of said needle inserted in the surface of skin of the
11 subject.